

Compensation of Gravity-Induced Structural Deformations on a Beam-Waveguide Antenna Using a Deformable Mirror

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At the NASA Deep Space Network (DSN) Goldstone Complex, located in the Mojave Desert in California, a 34-meter-diameter beam-waveguide (BWG) antenna, DSS - 13, was constructed in 1988--1990 and has become an integral part of an advanced systems program and a test bed for technologies being developed to introduce Ka-band (32-GHz) frequencies into the DSN. The antenna efficiency at 32 GHz was found to depend significantly on the elevation angle, i.e., it decreased from 45% to 35% as the elevation angle changed from 45 degrees to 20 degrees. This elevation angle dependence is due to the deformation of the main reflector caused by the resulting change in gravitational force applied to the antenna structure.

A method for compensating the gravity-induced structural deformations in a large ground-based beam-waveguide antenna is presented. A deformable flat plate (DFP) is installed at the M6 mirror location in the beam-waveguide optics as shown in Figure 1. The mirror consists of 49 deforming actuators that adjust the front skin to correct for the distortions in the main reflector surface. The initial approach was to use the holographical y derived main reflector astigmatism deformation pattern (recorded on January 18, 1992) and then to compute the necessary DFP surface to maintain uniform antenna aperture amplitude and phase. Aging or any other mechanical changes occurring after the initial holographic measurement can make the prediction for the actuator displacements sub-optimal. This apparently was the case at the start of the September 15--21, 1994 tests at DSS-13. At 12.7-degrees elevation, the main reflector surface deformation was different than on January 18, 1992. However, the deformation was similar enough to make a good initial estimate of the surface. Subsequent holographic imaging of the antenna surface in near-real time (16 minutes) successfully derived new displacement adjustments for the DFP actuators. The application of the holographic technique to "tune" the DFP in the field resulted in an additional 1.0-dB performance improvement at Ka-band at the elevation angle of 12.7 degrees.

Deformable Flat Plate Design: The deformable mirror is a 27-inch-diameter, 0.040-inch-thick sheet of 6061 -T6 aluminum with 49 supports arranged as shown in Figure 2. A single station is shown in Figure 3. The aluminum sheet (#4 in Fig. 3) is supported by 496-32 studs (#2 in Fig. 3), each of which is bonded to the aluminum disk. The mirror end of each stud is increased in diameter by a small mechanically attached intermediate disk to provide adhesive bond area for sufficient strength to deform the mirror. The opposite end of each support stud (#2) is threaded into a brass bushing (#1) which has a #6-32 thread on the inside and a

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7/16-20 thread on the outside. One end of the bushing is slotted so that it can be rotated with a screwdriver (or stepper motor for an automated version). The bushing external thread engages a tapped hole in a 3/4-inch-thick aluminum plate (#3). When assembled, rotation of the brass bushing results in an axial movement of the stand-off to which the mirror is attached relative to the support plate. The differential thread system allows relatively large rotations of the bushing for comparative y small axial movements of the **mirror** station.

The Experiment: An initial low-cost demonstration of the technique was performed at DSS-13 using a fixed elevation angle and a manually adjustable DFP. Microwave holography was used at an elevation angle of 12.7 degrees to obtain a surface distortion map of the main reflector: 1) with a undistorted flat plate and 2) after the calculated correction had been applied to the DFP. Near-real-time holography was then used to adjust the surface to obtain the lowest **RMS** surface obtainable within the short time available for the experiment. The RMS was improved from 0.59 mm for the initial no-correction flat plate to 0.49 mm for the initial analytically derived correcting surface and, finally, to 0.36 mm for the holography-derived DFP. This would represent an improvement of approximately 2.0 dB at 32 GHz.

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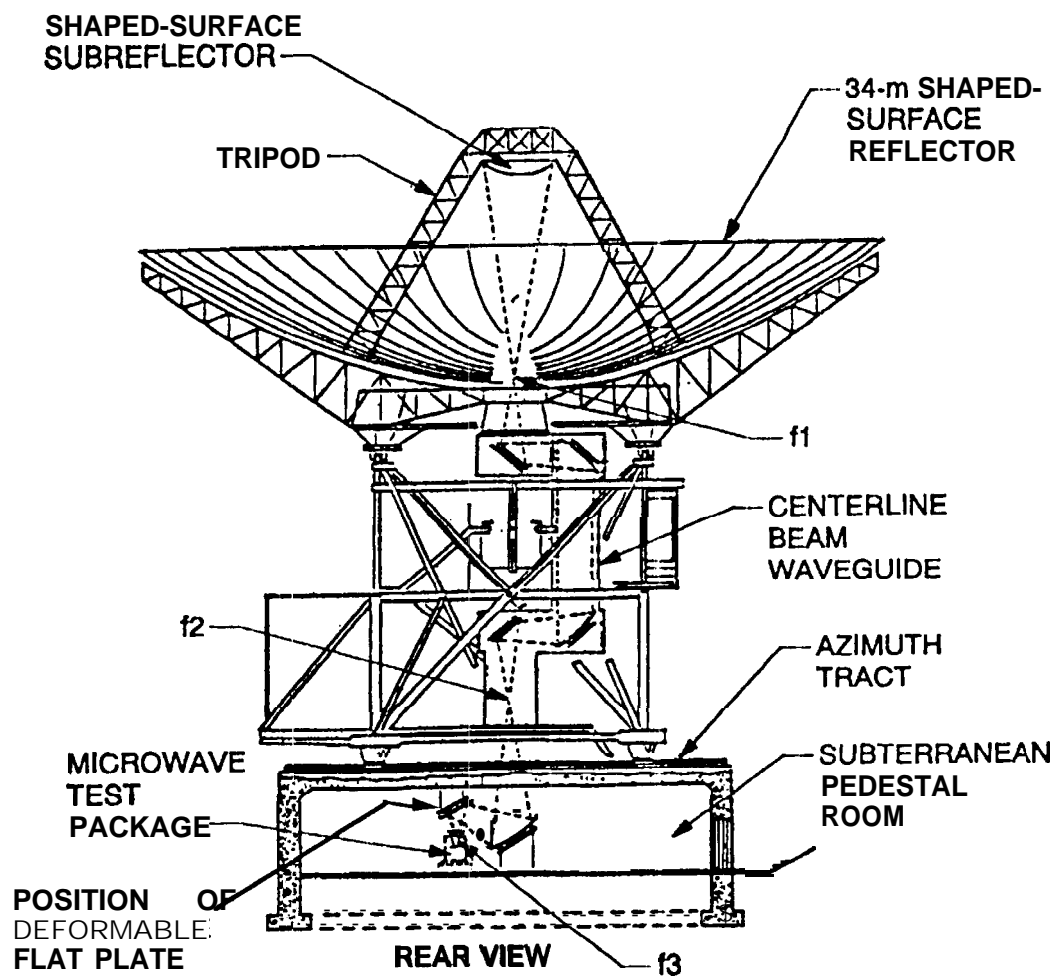


Figure. 1. The 34-meter Beam-Waveguide Antenna

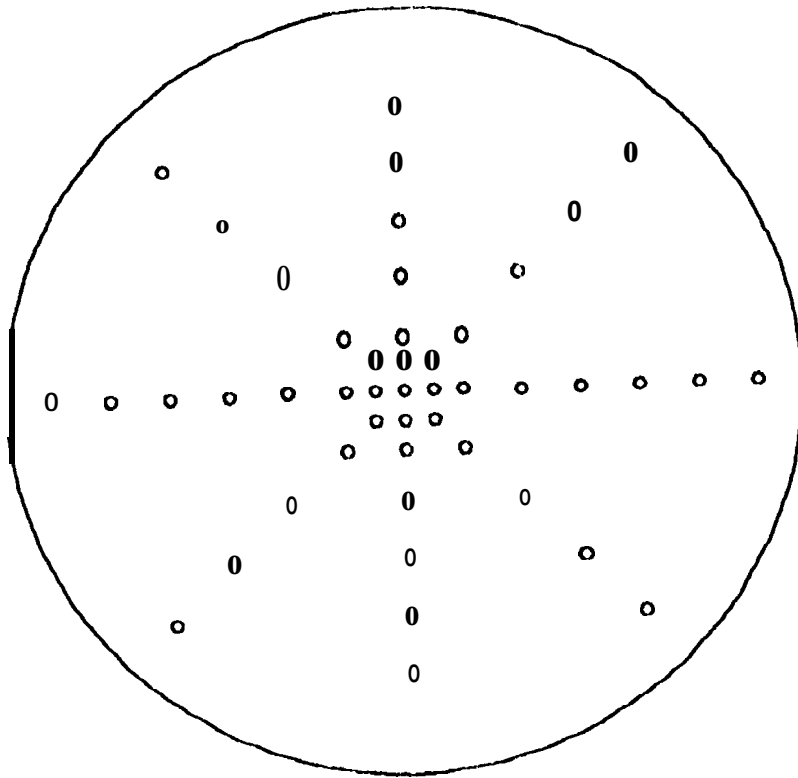


Figure 2. Position of 49 Supports for DFP

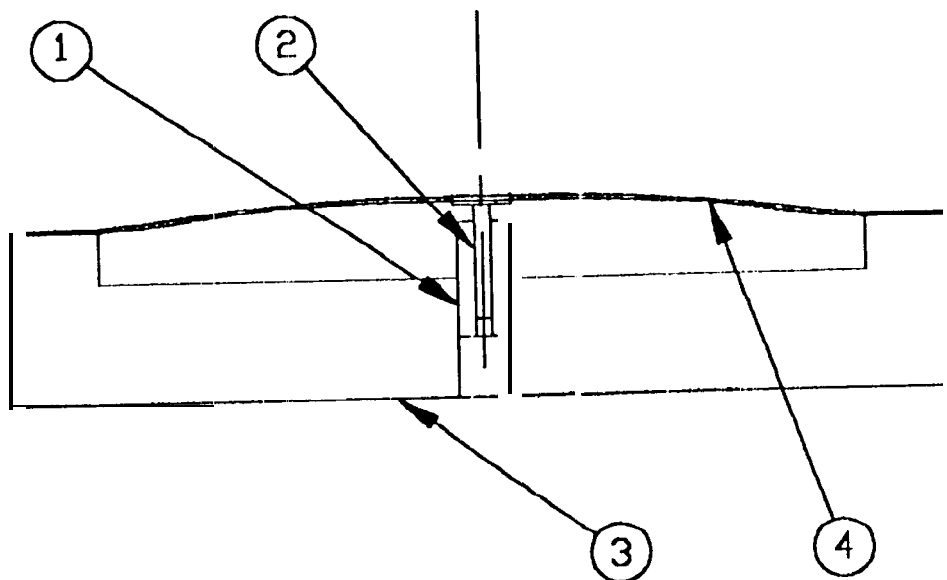


Figure 3. Mechanical Actuator for Supports